Virtual Combat Vehicle Experimentation for Duty Cycle Measurement (2008-01-0776)

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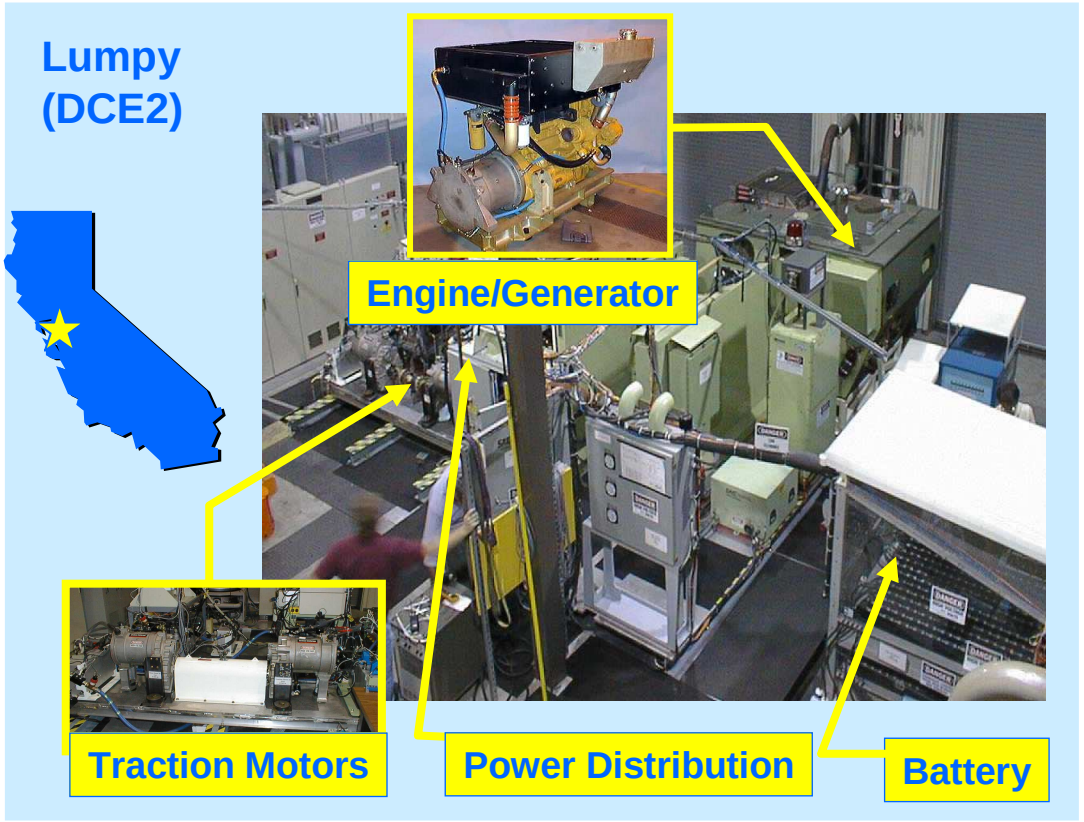
Outline

- Motivation and Purpose
- Experiment Design
- Simulation Architecture and Design
- Results and Conclusion

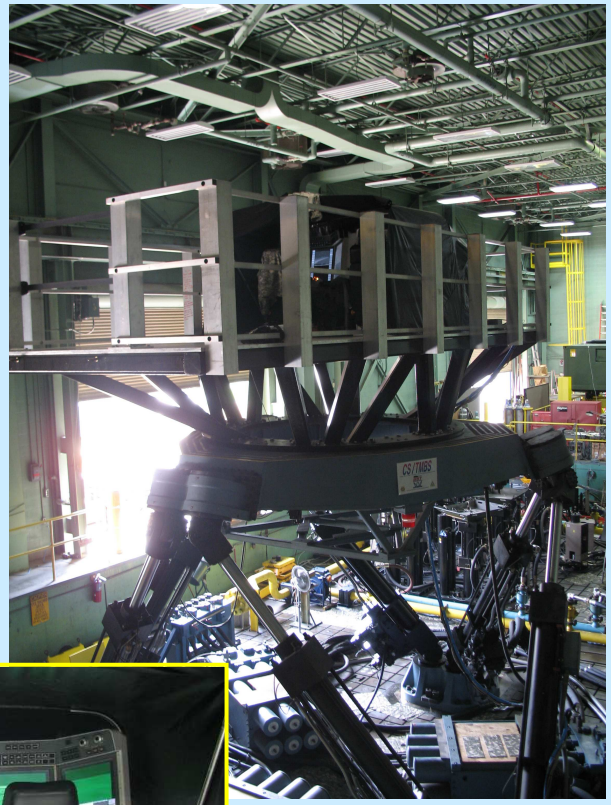
P&E SIL

- Series Hybrid-electric power system
- Laboratory based evaluation of design alternatives
- Driven by automated controller
- Requires a-priori duty cycle



TARDEC Simulation Lab (TSL)

- Man-rated motion base simulation lab
- Integrated immersive simulation environment
- Real-time vehicle models
- Integrated CAT Crewstation
- Integrated simulated forces simulation



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Duty Cycle Experiments (DCE)

- Work is done for TARDEC Ground Vehicle Power & Mobility (GVPM) R&D Group
- Began in 2005
- Measure the "duty cycle" of a military vehicle in a relevant scenario.
- Use a high-resolution simulation environment to stimulate realistic behaviors.
- Measure mobility and non-mobility loads.
- Data are used by GVPM to develop power systems.

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Duty Cycle: Definition

A military vehicle's *duty cycle* is specific to the mission and platform type but is a design- and configuration-independent representation of events and circumstances which affect power consumption.

Such events and circumstances encompass (1) vehicle operation along the course such as speed, grade, turning, turret/gun activity, and gun firing plus (2) external scenario components that affect power consumption like incoming rounds, ambient temperature, and soil conditions.

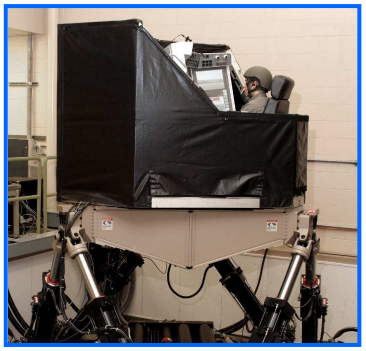
The event inputs can be distance based when the vehicle is moving or time based when the vehicle is stationary, or even triggered with some other state condition.

Experiment Purpose

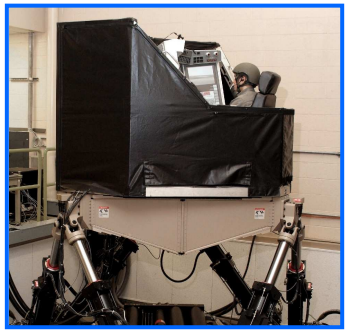
- To measure the duty cycle of a Future Combat Systems (FCS) Mounted Combat System (MCS) in a relevant scenario.
- Build a high fidelity representation of the vehicle and power system.
- Bring in professional operators to run the simulation.
- Operate in real-time with the P&E SIL by integrating it over the Internet.

Past Work

- DCE1



- DCE2



	DCE1	DCE2	DCE3
Date	Nov '05	June '06	May '07
Participants	Civilian	Military	Military
Runs	7	12	12
Scenarios	1	1	2
Vehicles	1	1	2
Roles	Drive	Drive/Gun	Drive/Gun
Motion base	RMS	RMS	TMBS
Length	11 km	13 km	61/38 km
Duration	25 min	25 min	100/40 min
Long Haul		Yes	Yes
BLOS			Yes
NV/IR			Yes
Moving troops			Yes
Wingman			Yes

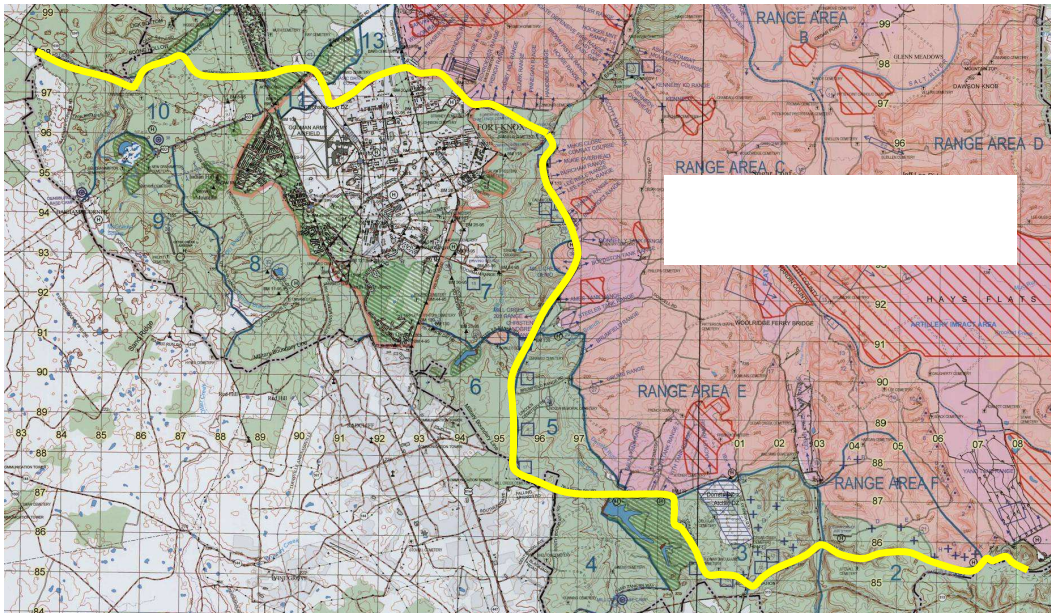
Experimental Design: Vehicle

FCS-MCS

- 27 Ton chassis
- Series hybrid-electric drive
- Includes defensive and offensive weapon systems.

Experimental Design: Terrain

- Used a Continental US location for the experiment.
- One-way route is approximately 19 mi (31 km) long.
- 394 ft (120 m) elevation range
- -20% to +39% grade range.
- 3.9% mean absolute grade.



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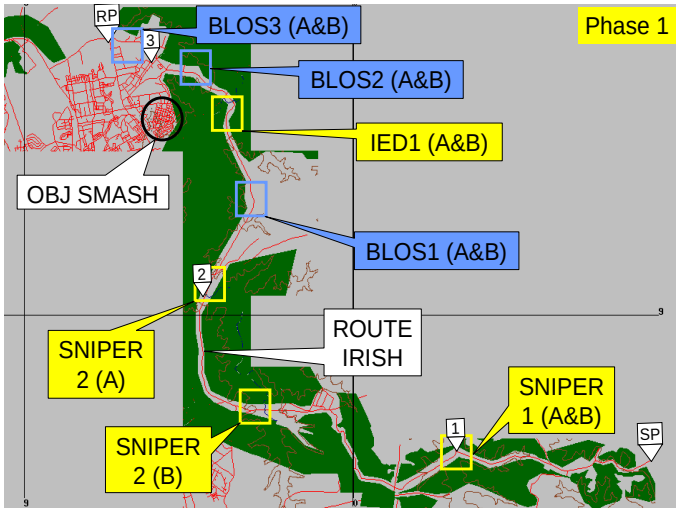
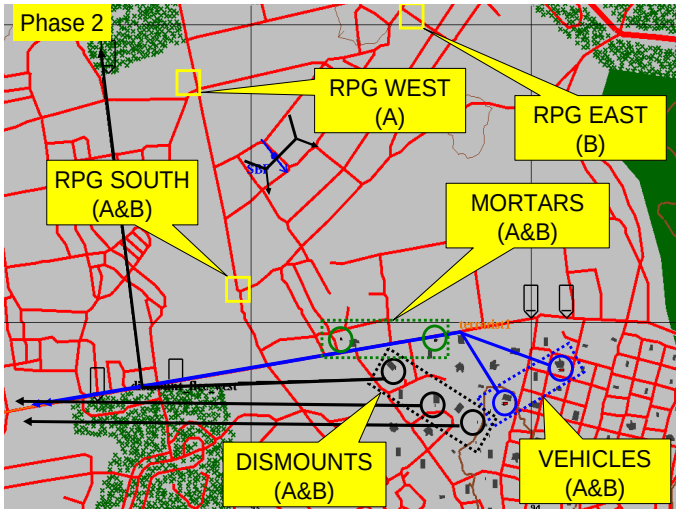
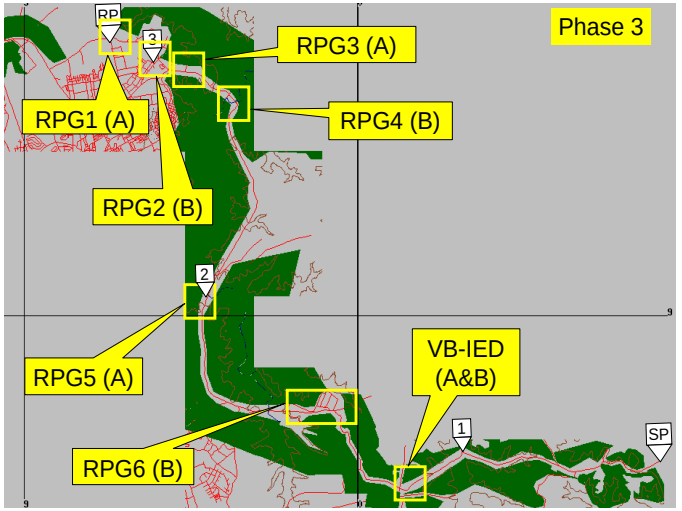
Experimental Design: Scenario 1

UAMBL: 3 phases

1. Advance to objective
2. Support by fire
3. Exfiltrate



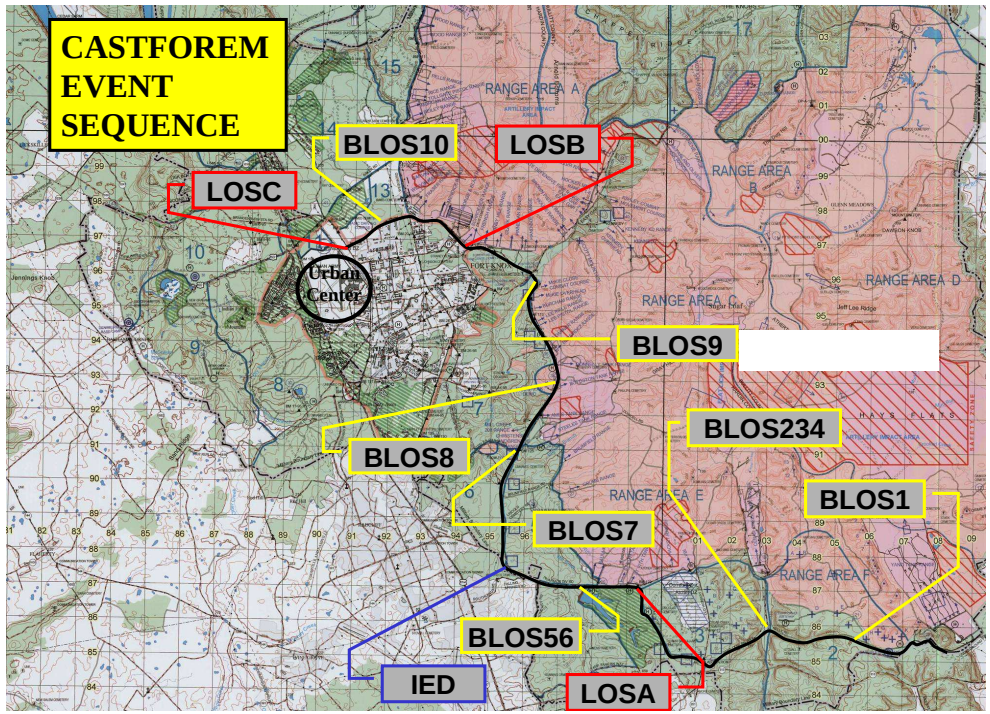




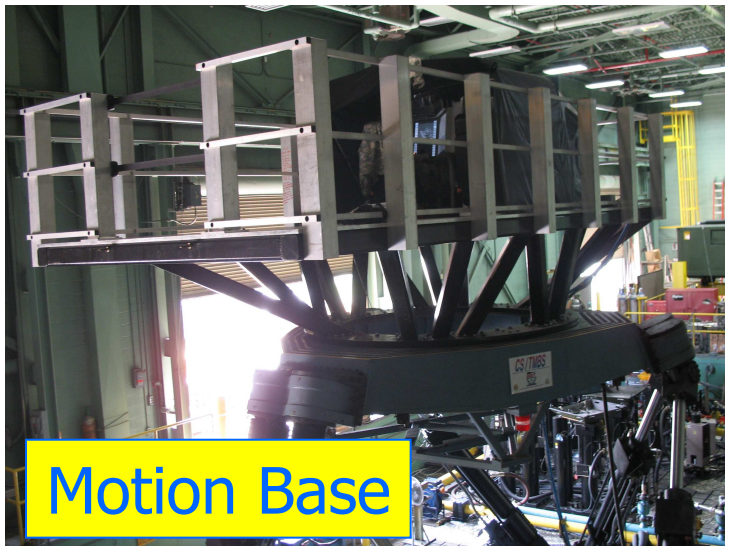
Experimental Design: Scenario 2

CASTFOREM (Single phase).

- Advance to objective.
- Conduct Line-of-sight (LOS) and Non-line-of-sight (NLOS) engagements.
- Await further orders.



Experimental Design: Crew Stations



Motion Base

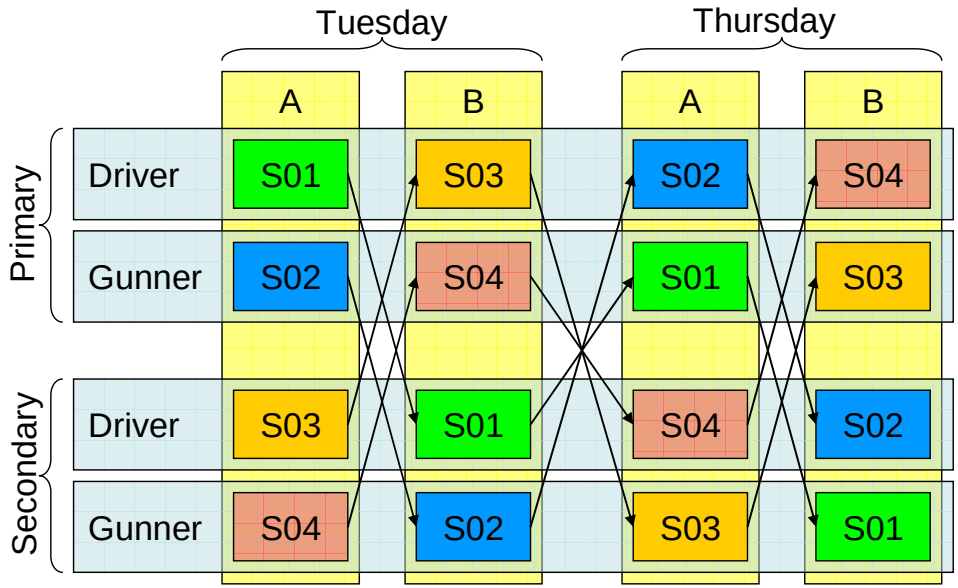
Primary Gunner/Driver

Secondary Gunner

Secondary Driver

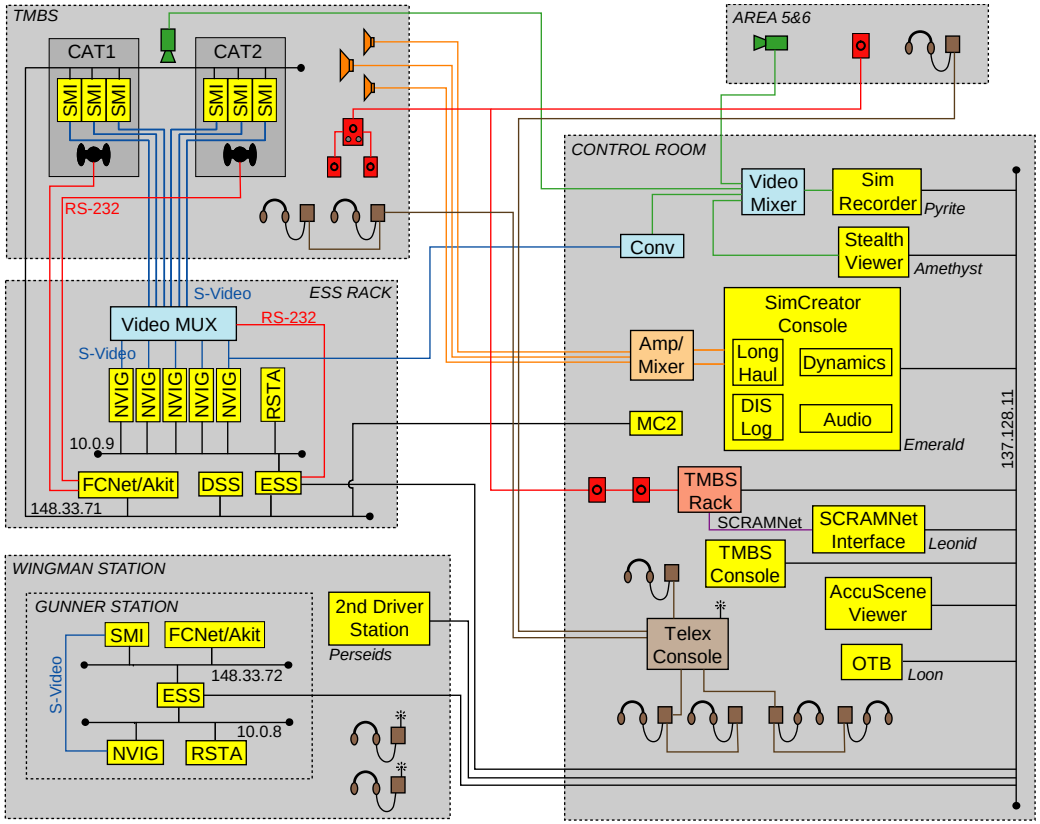
Experimental Design: Run Matrix

- 4 soldiers per week.
- Each soldier runs as
  - Primary team
  - Secondary team
  - Driver
  - Gunner
- Practice & training are on Mon. and Wed.
- Record runs on Tues. and Thurs.
- A & B variants of the scenario.



Architecture and Design

- 29 Computers
- Motion: TMBS
- Visuals:
  - IG by Night Vision Labs
  - GeForce 7800 GT
- Dynamics:
  - SimCreator® Multi-body Dynamics
  - Custom track model
  - Simulink® power train
- Infrastructure:
  - SimCreator
  - 100Base/T Ethernet and SCRAMNet
- Driver Interface:
  - 2 CAT crewstations
  - Secondary crewstations

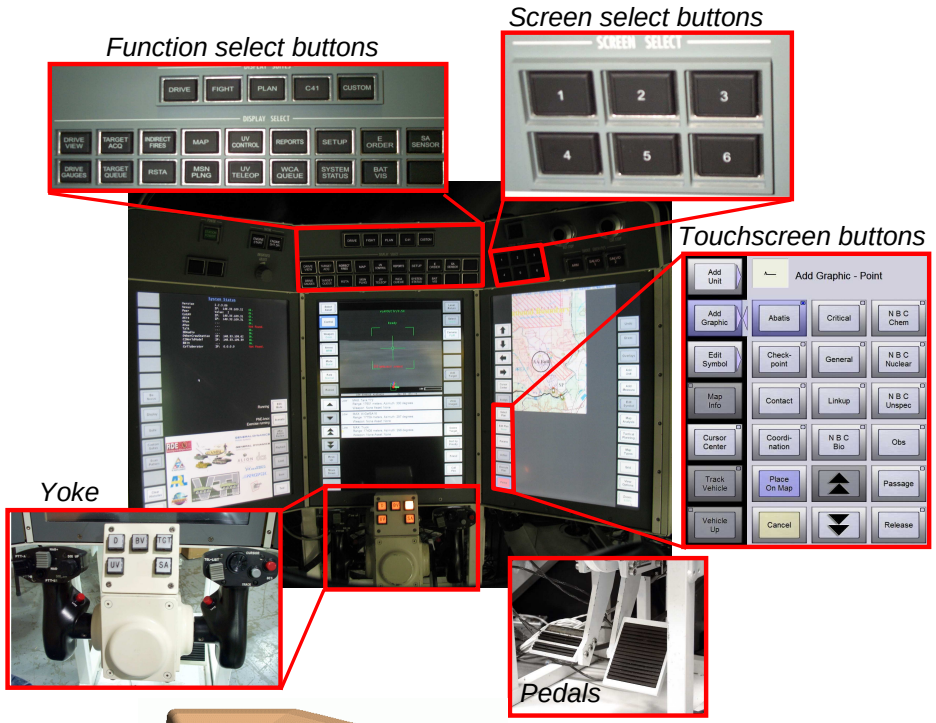


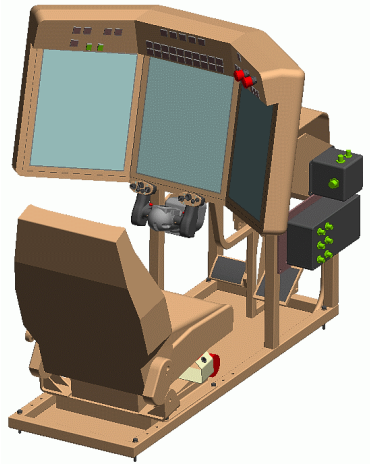
Architecture and Design: CS/TMBS

- Crew Station / Turret Motion Base Simulator (CS/TMBS)
- 6 DOF
- 50,000 lb (22,680 kg)
- Multi-occupant
- Hydraulically powered.
- 10 Hz bandwidth

Architecture and Design: CAT Crewstation

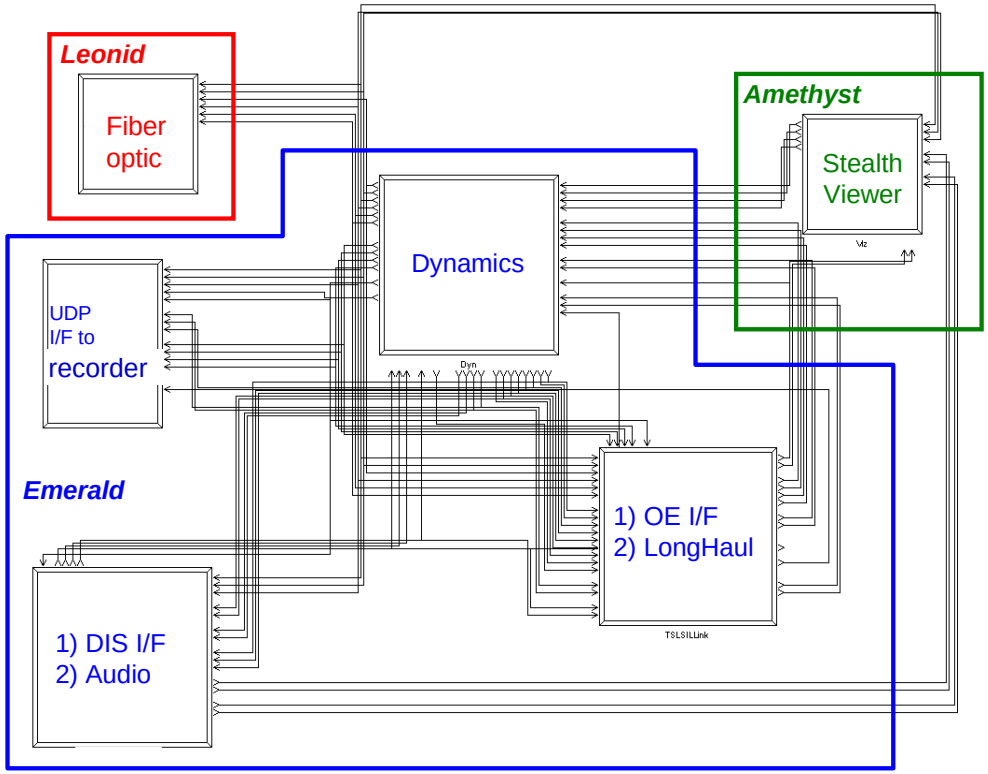
- Crew-integration and Automation Testbed (CAT) Crewstation
- Three 17”x13” touch screens
- Six virtual screens
- Yoke, pedals
- Hard/soft buttons
- Multi-role support





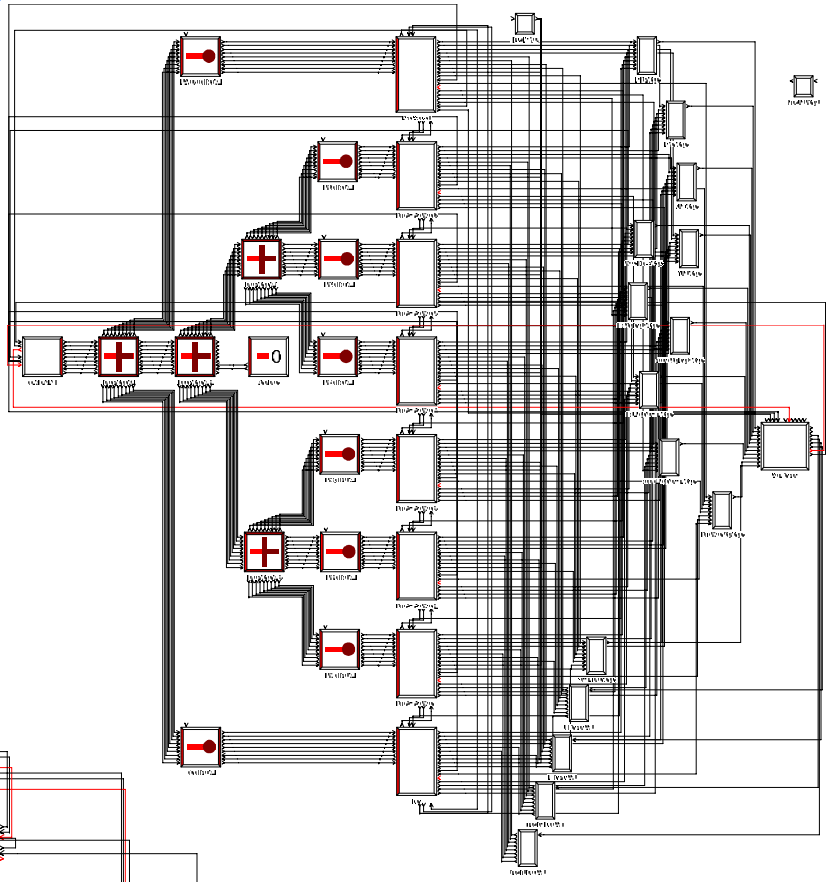
Architecture and Design: Infrastructure

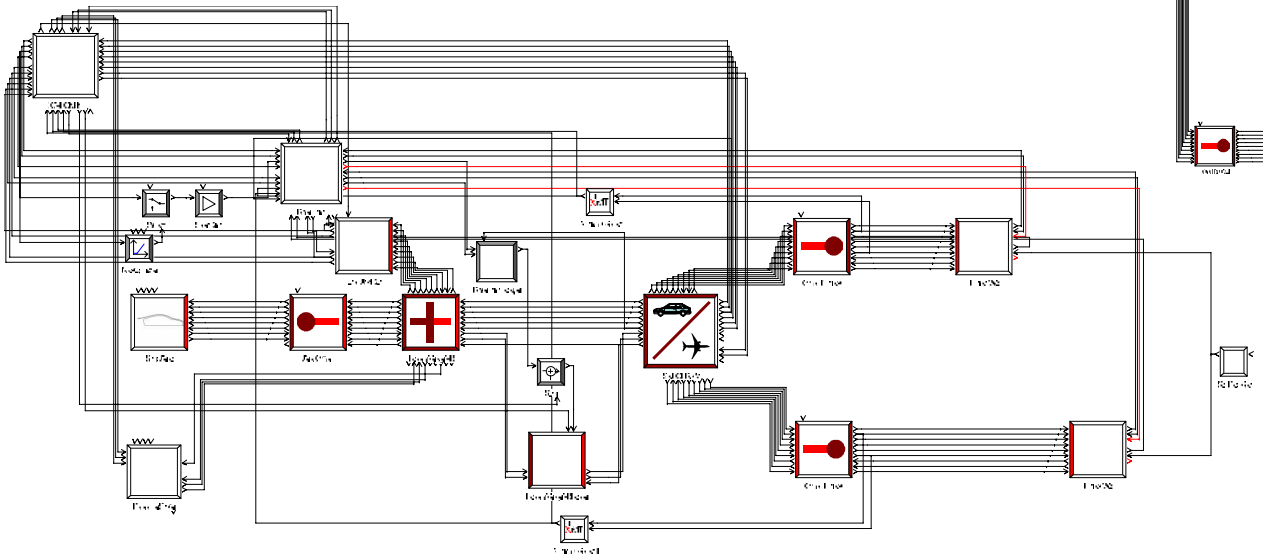
- Multi-infrastructure:
  - Commercial Integration Software (shown)
  - Distributed Interactive Simulation (DIS)
  - Operating Environment (OE)
  - Long Haul (custom)
- Network
  - Three subnets
  - UDP/IP
  - Fiber optic deterministic network.



Architecture and Design: Vehicle Dynamics

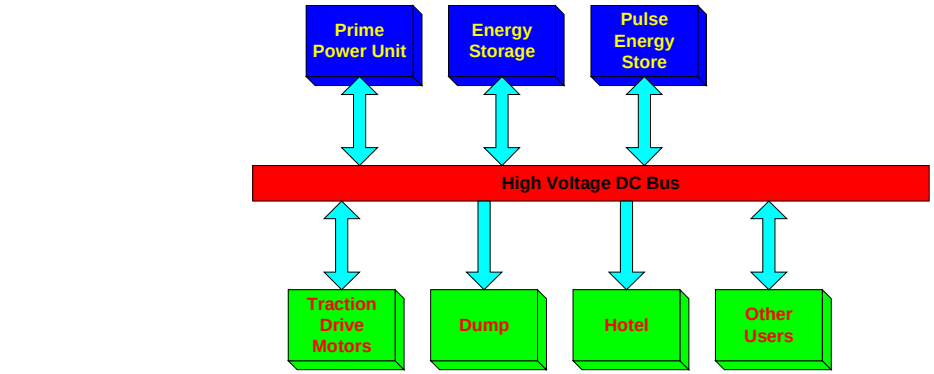
- 15-body model using a commercial real-time modeling tool.
- Trailing-arm suspension, turret, gun
- Skid steer with track model

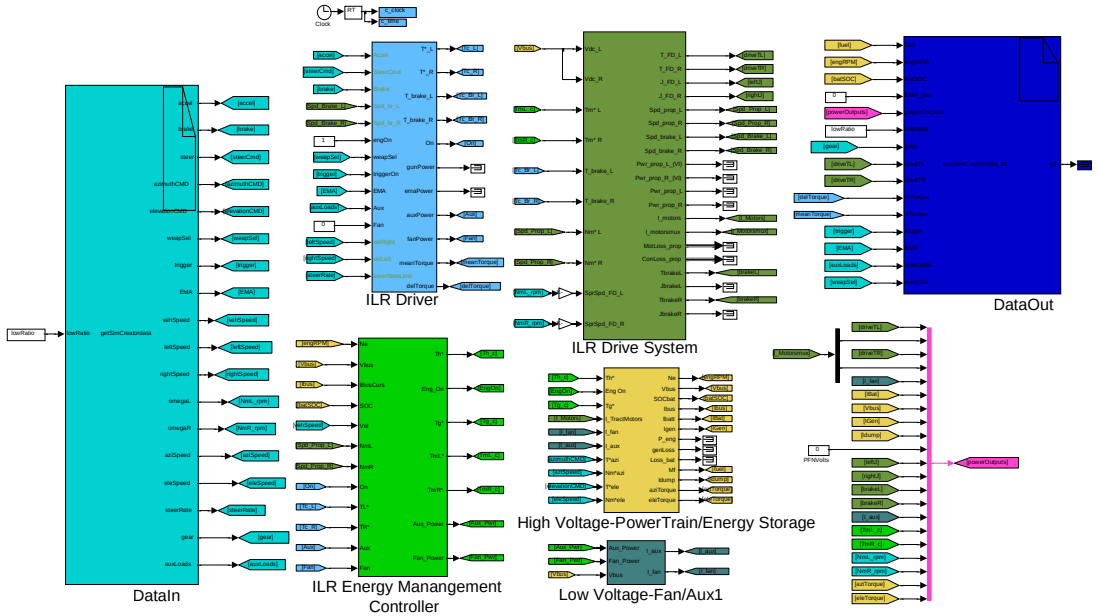




Architecture and Design: Power System

- Series Hybrid-electric
- Implemented in commercial modeling tool
- Generate C-Code using commercial code generator
- Integrate into integration framework as a component





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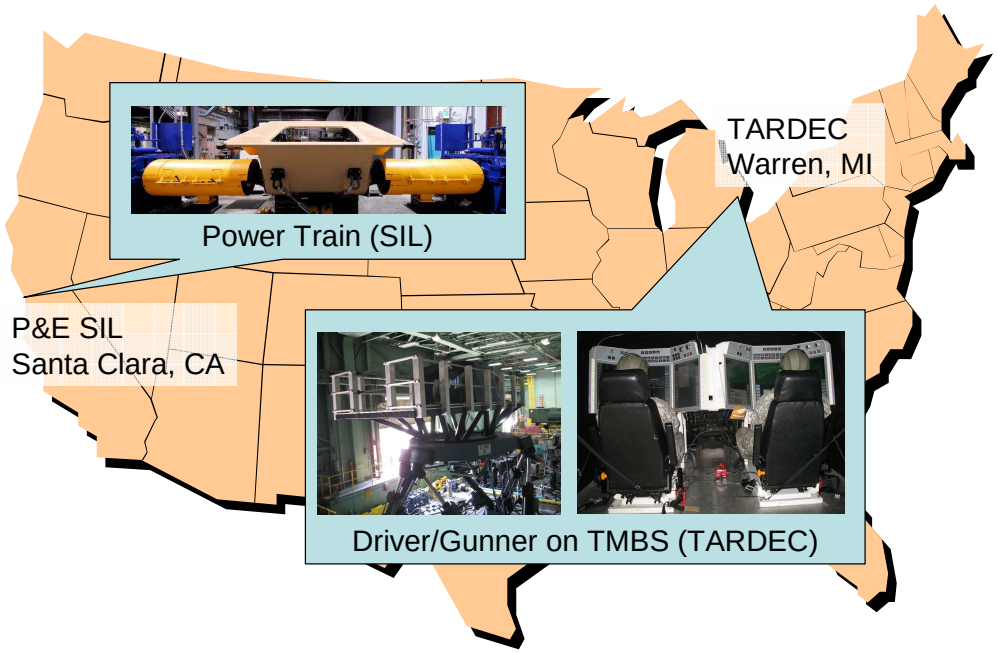
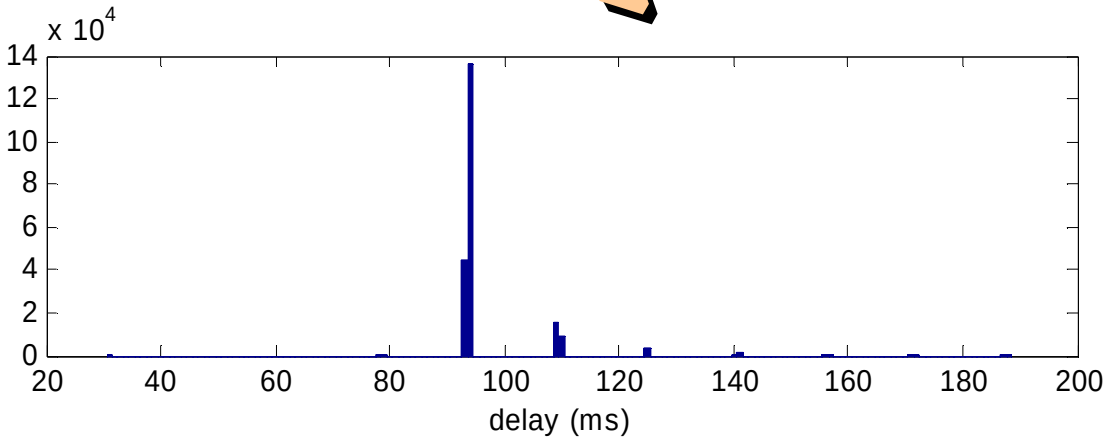
Long Haul Connection

- Operate the TMBS with the SIL in real-time.
- 2,450 mile separation
- 94 ms round trip time
- Internet as communication channel





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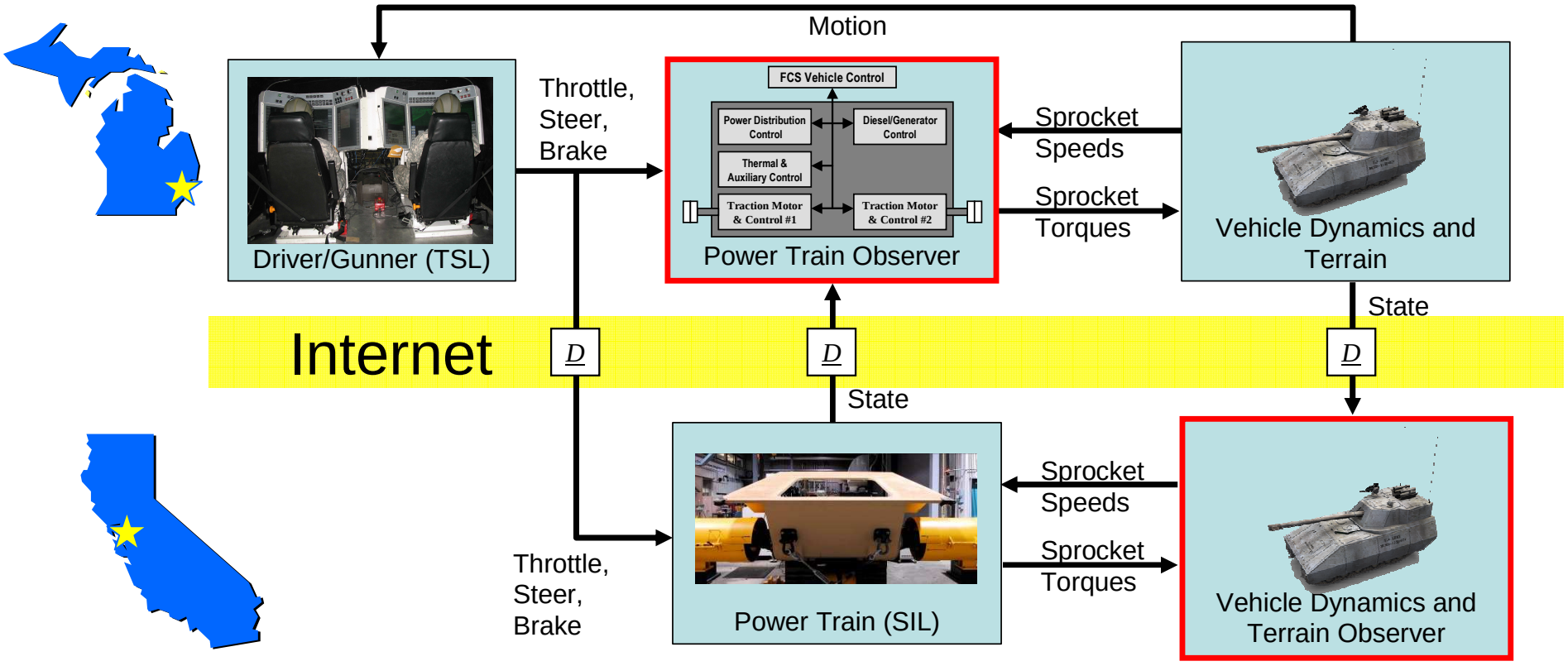
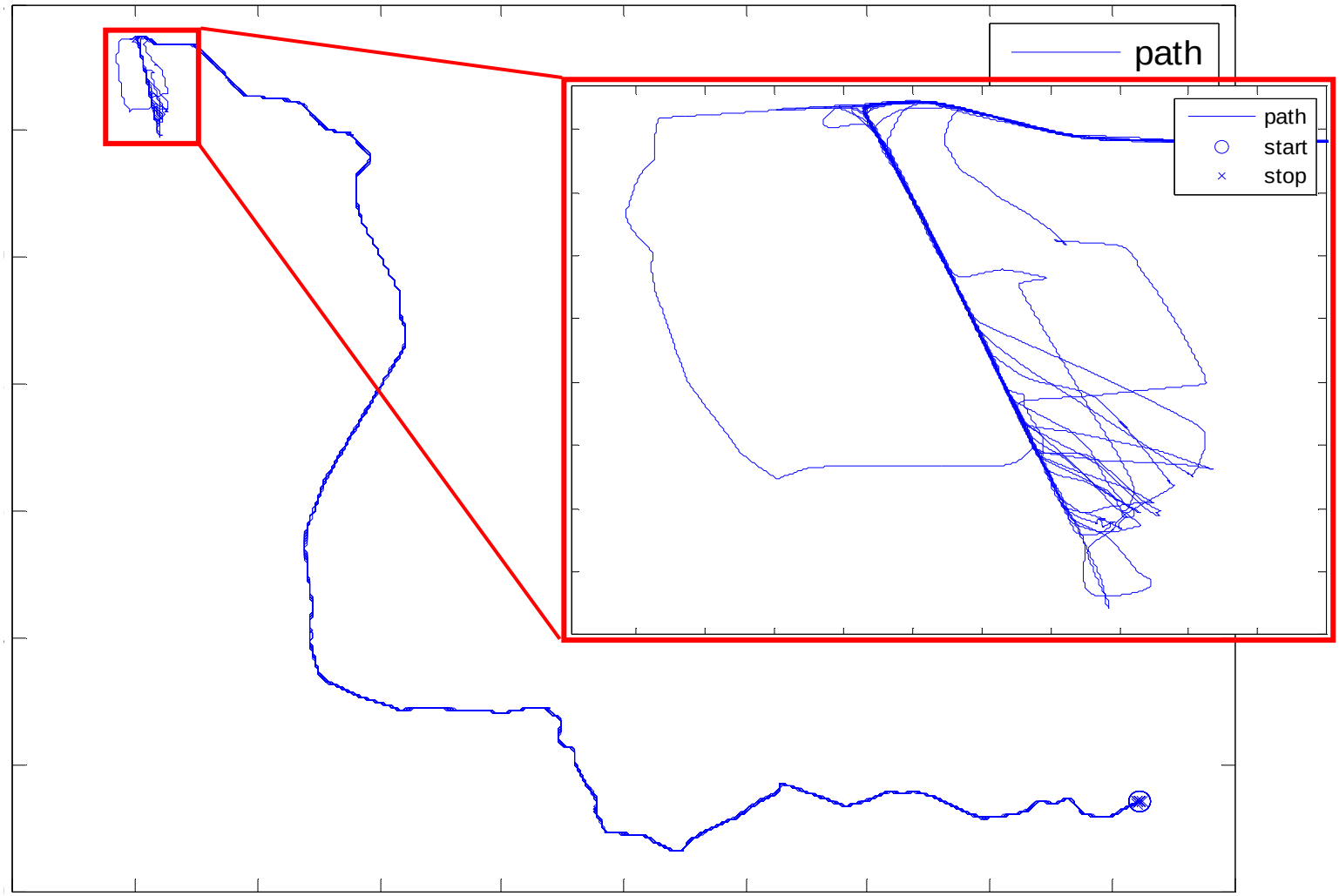
Long Haul Connection: Design



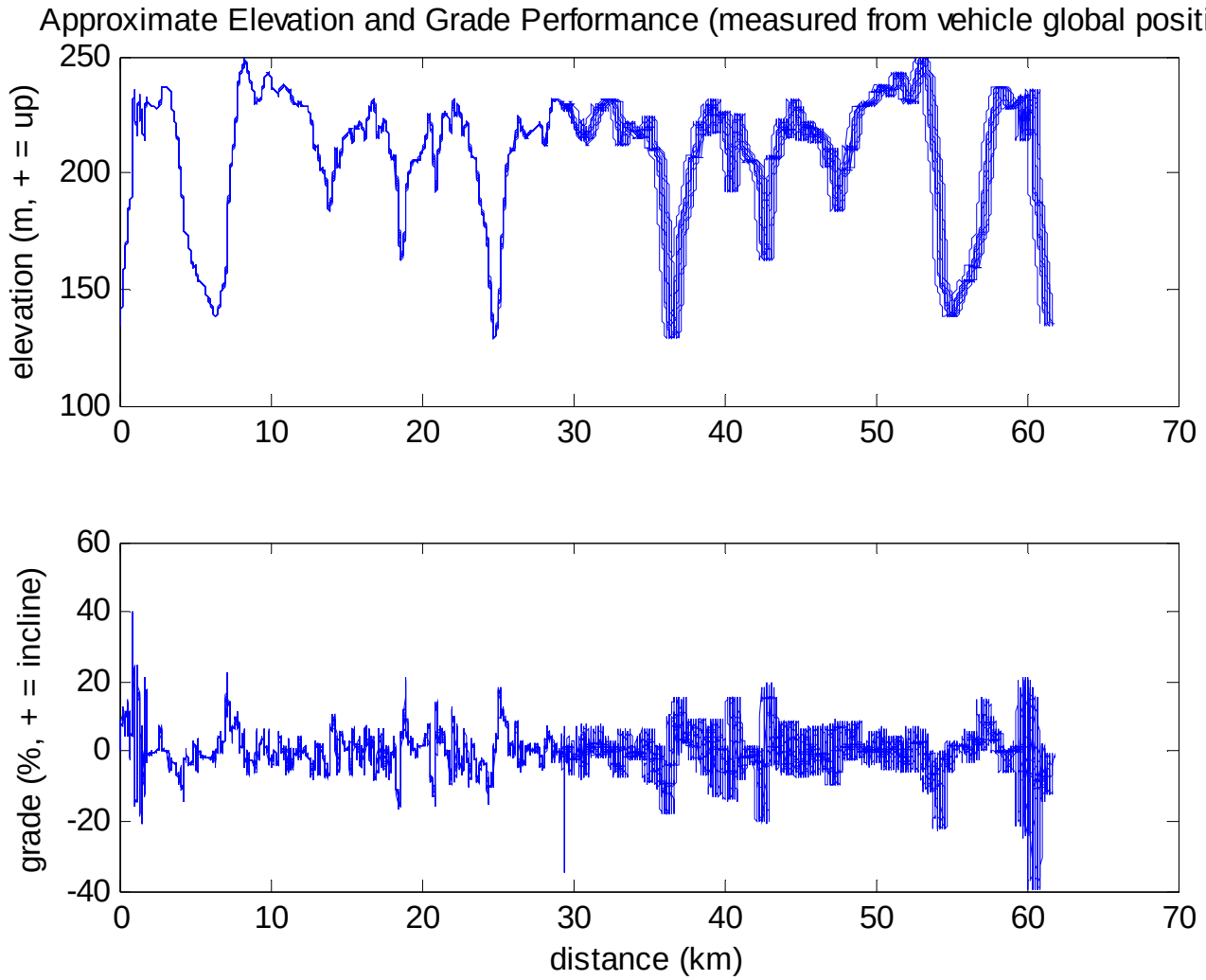
Results

- 12 soldiers participated.
- 3 weeks
- Recorded:
  - Vehicle position, velocity
  - Power System states
  - Operator commands
  - Force activities

Results: Path



Results: Elevation & Grade



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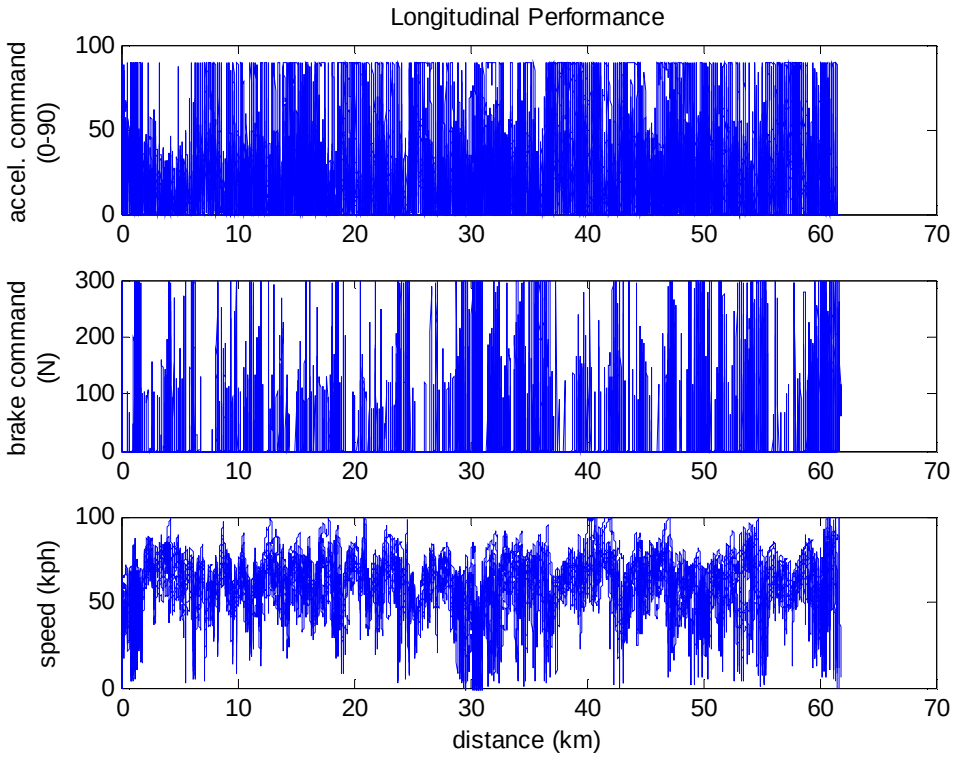
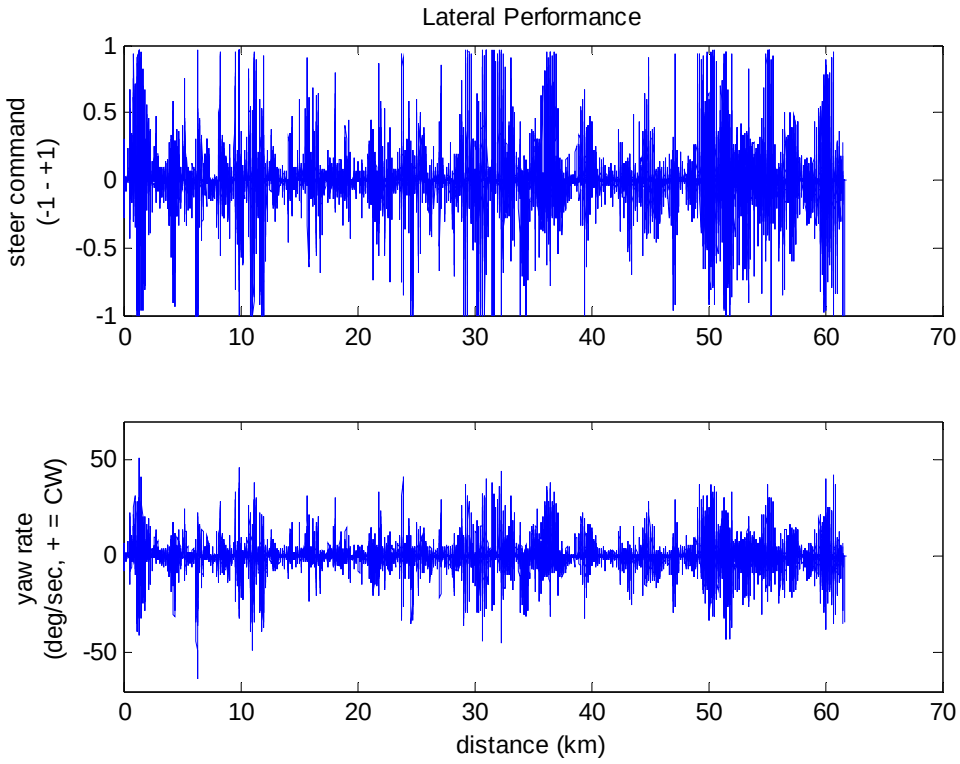
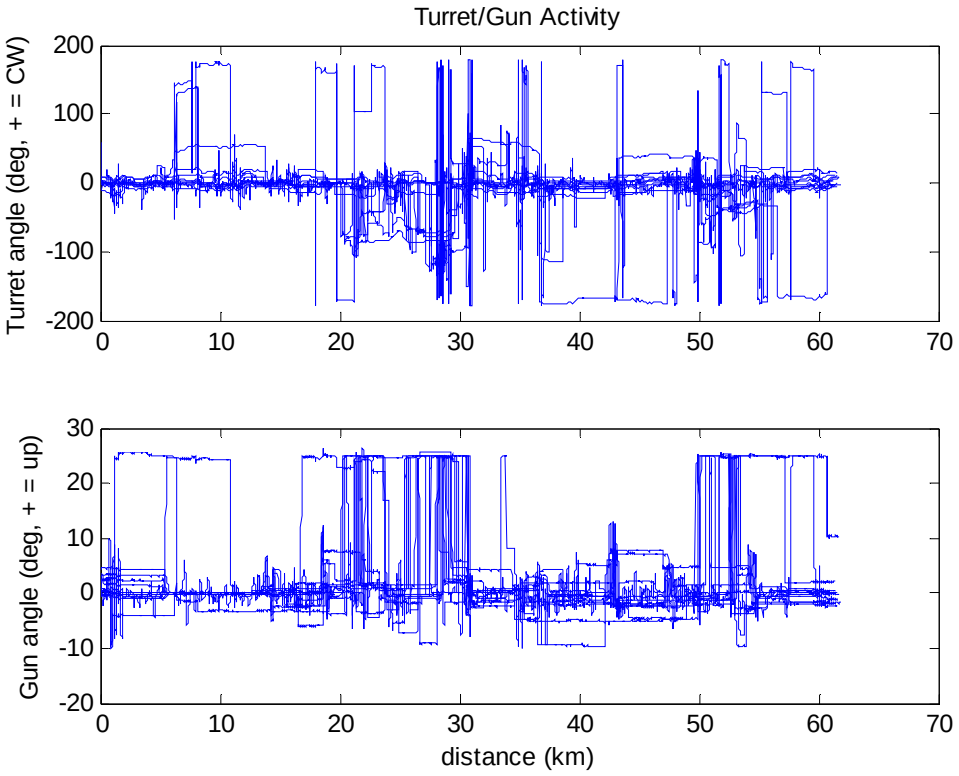
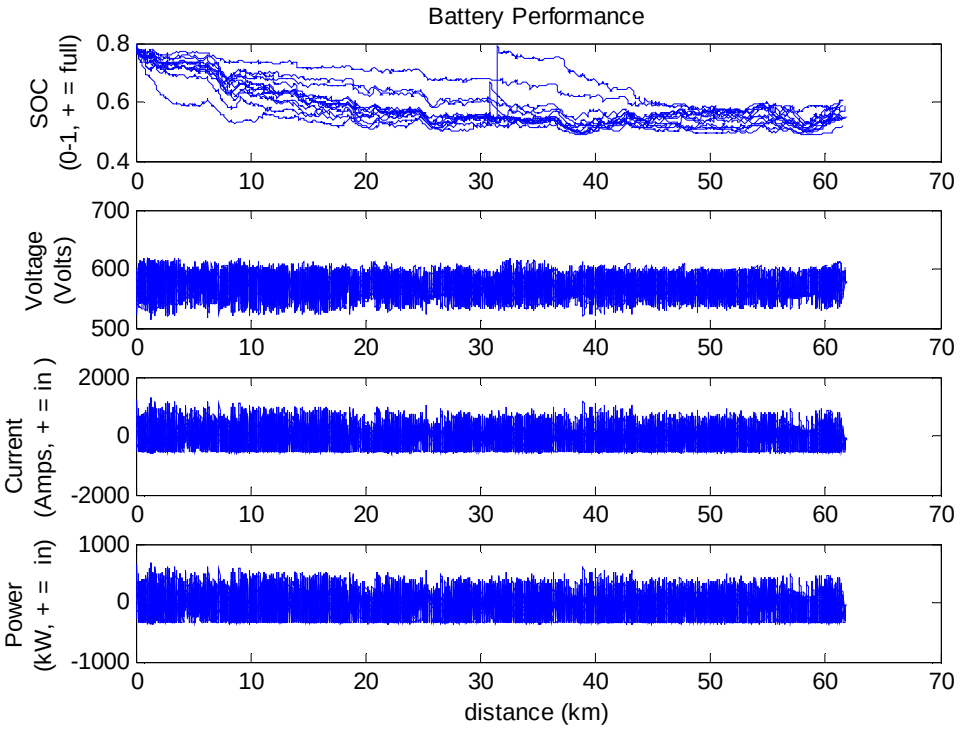
Results: Driver Commands





Results: Turret/Gun & Battery





Conclusion

- An experiment was designed to measure duty cycle of a future combat systems (FCS) mounted combat system (MCS) in a relevant operational environment.
- It involved the integration of:
  - Real-time vehicle dynamics
  - A power system model
  - The Power & Energy SIL
- It successfully measured a set of 12 duty cycles for two different scenarios.